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Low Voltage Modulators Based on Semiconductor Microresonators

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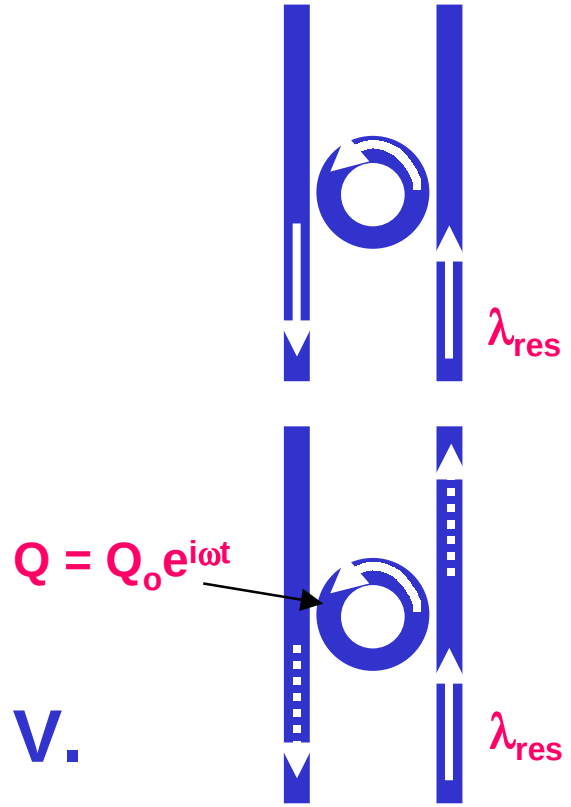
Program Concept

- High Q resonators enhance the coupling between waveguides.
- Low voltage modulation of the resonator Q can modulate the power transfer.
- Develop techniques for fabricating resonators and modulator circuits with $V_p \sim 0.1$ V.



μ Resonator Structures

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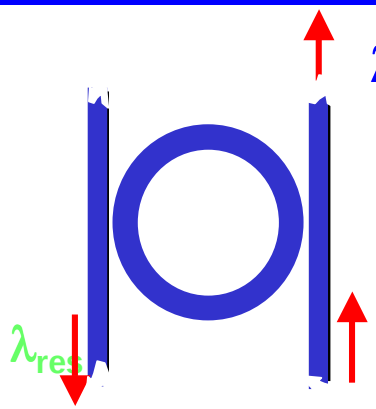
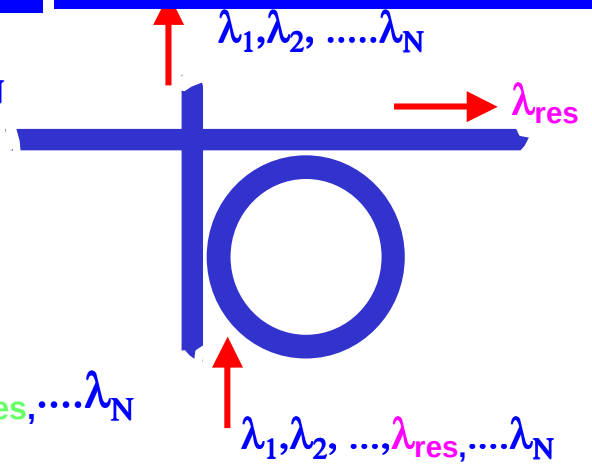
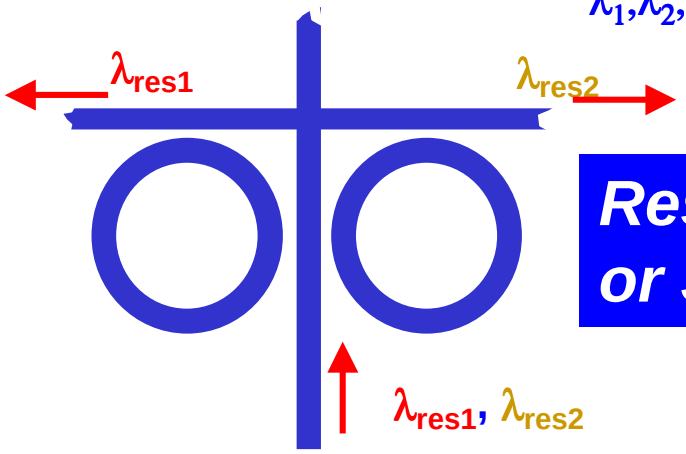
Resonant Filter / Switch



Resonant Y or Splitter

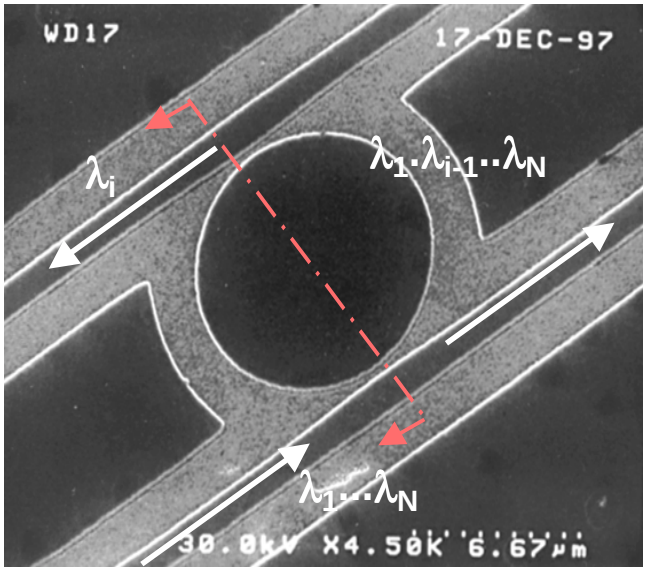


- Add-Drop Filters
- Resonant Detectors
- Integrated Lasers
- Resonant Modulators



Resonant T or Splitter

Laterally Coupled Resonator



- Air coupling and guiding
- Submicron control of coupling
- Submicron waveguide widths
- Control of waveguide and resonator wall smoothness

Vertically Coupled Resonator

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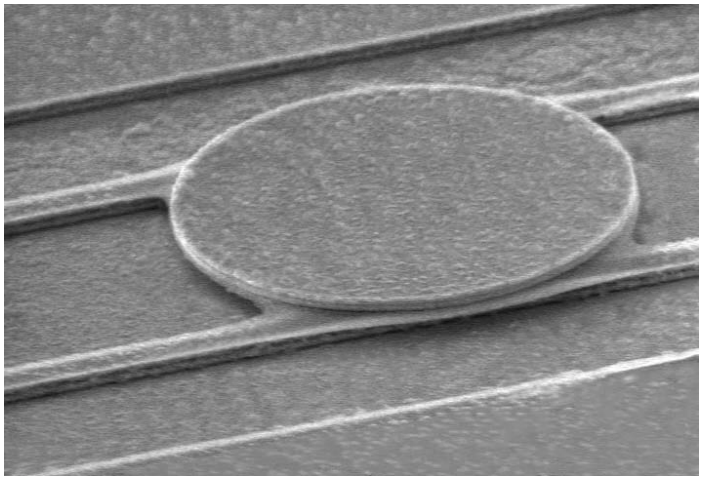
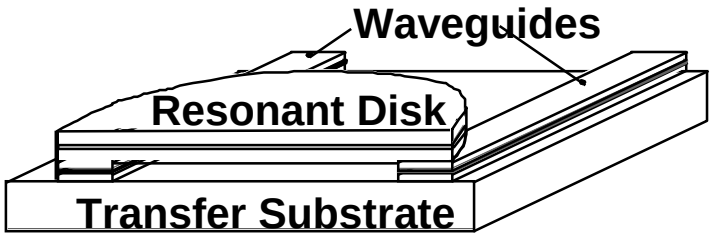
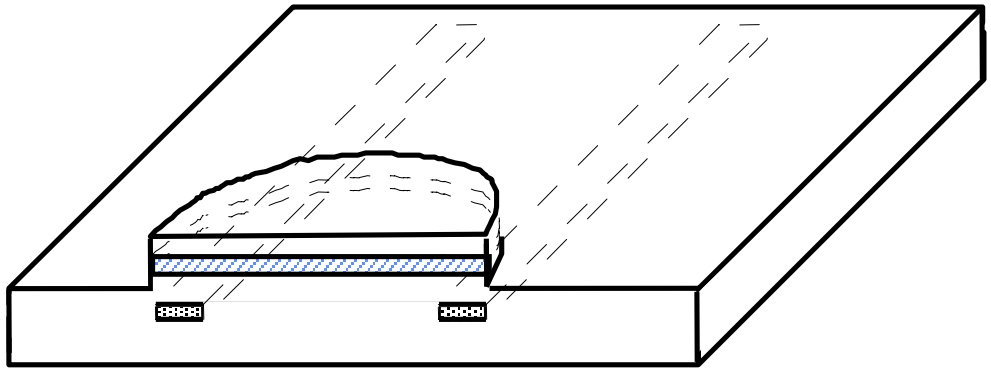




- Epilayer coupling.
- Control coupling by epilayer thickness.
- Flexible single mode waveguide design.
- Integration of active and passive structures.
- Separates resonator and coupler fabrication

Integration Challenges



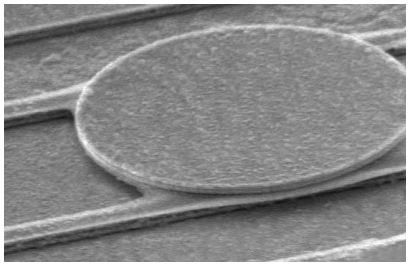
Uniform resonator potential / current flow

Buried or ridge waveguides?

Rings or disk resonator?

Regrowth or wafer bonding?

Loss and Q Control



Residual absorption in resonator

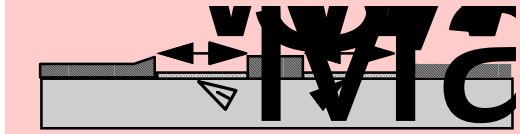
Scattering at edges

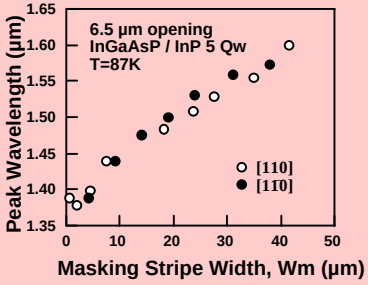
Controlled coupling

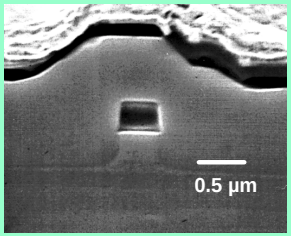
Insertion loss

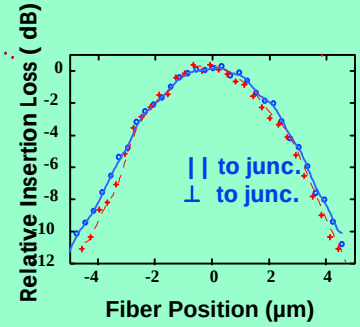
Mode matching

} **Tapered Mode Couplers**



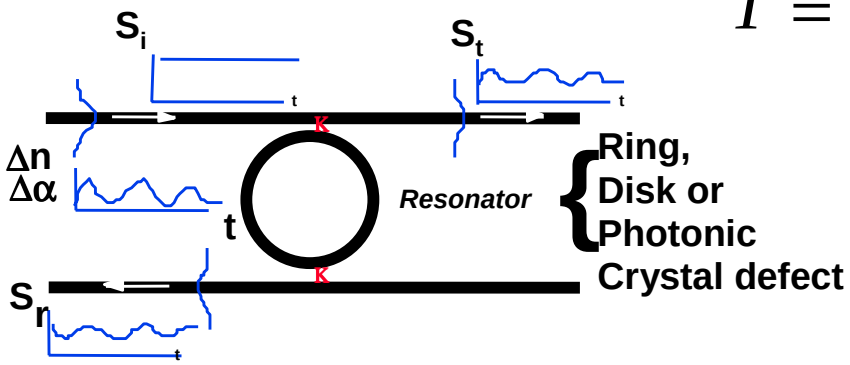






Resonator Response

$$T = \frac{j(\omega - \omega_0)/\omega_o + (Q_l^{-1} - Q_c^{-1})/2}{j(\omega - \omega_0)/\omega_o + (Q_l^{-1} + Q_c^{-1})/2}$$

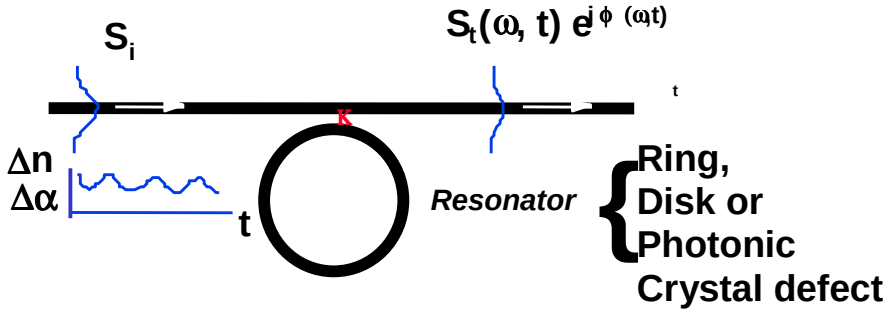


At resonance:

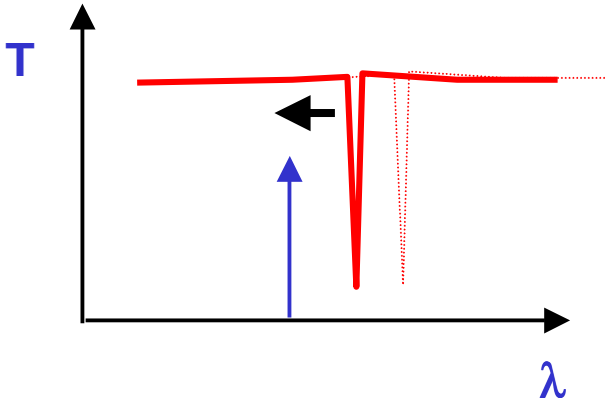
T is 0 when $Q_l = Q_c$

T exhibits a π phase change

T is a minimum unless $Q_l >> Q_c$ then T = 1

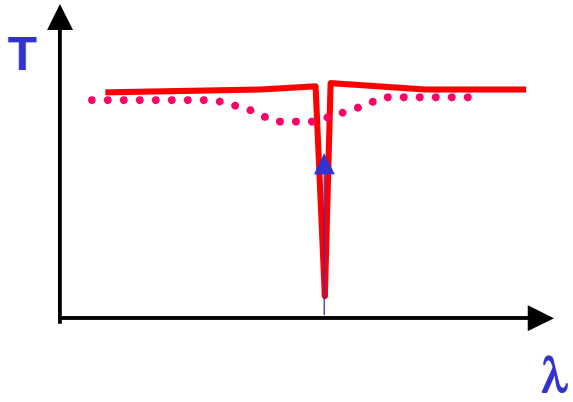


Modulation Mechanisms



Resonance Tuning

- Electro optic Effect
- Electroreflectance Effect
- Free Carrier



Q Tuning

- Electroabsorption
- Gain
- Electroreflectance

μ Disk Resonant Components

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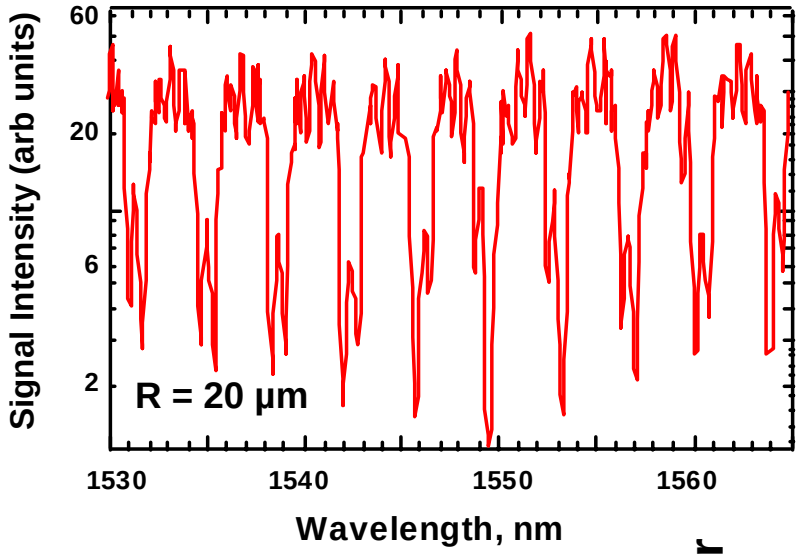
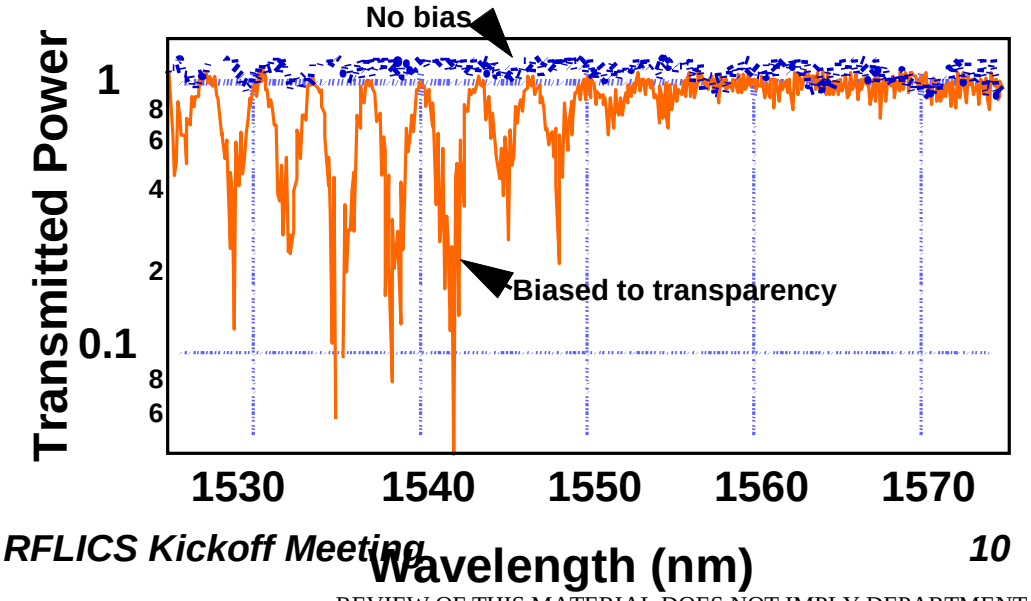
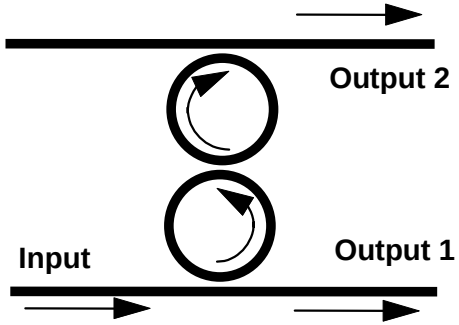


Passive μ disk coupler

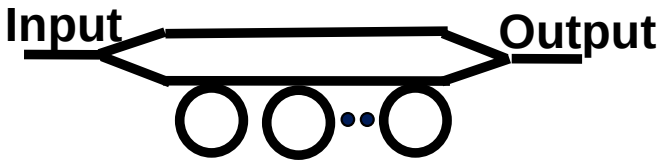
Active μ disk tunable filter / switch



Resonator Circuits



- Shaped Resonance Response
- Venier Resonance Control



- Traveling Wave Drive
- Additive Phase Changes
- Push Pull Drive

Modeling Tools

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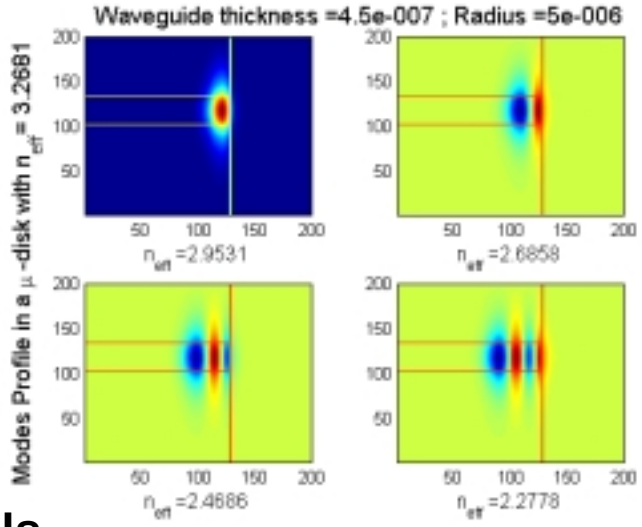
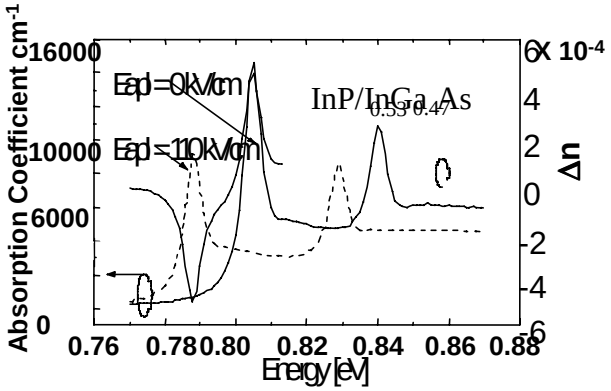
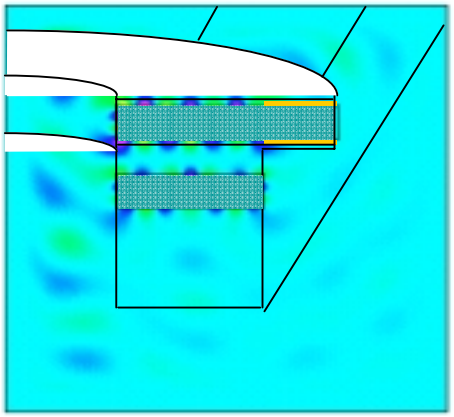
Finite Difference Mode Solvers



Physics Based Models



FDTD



Waveguide / resonator coupling

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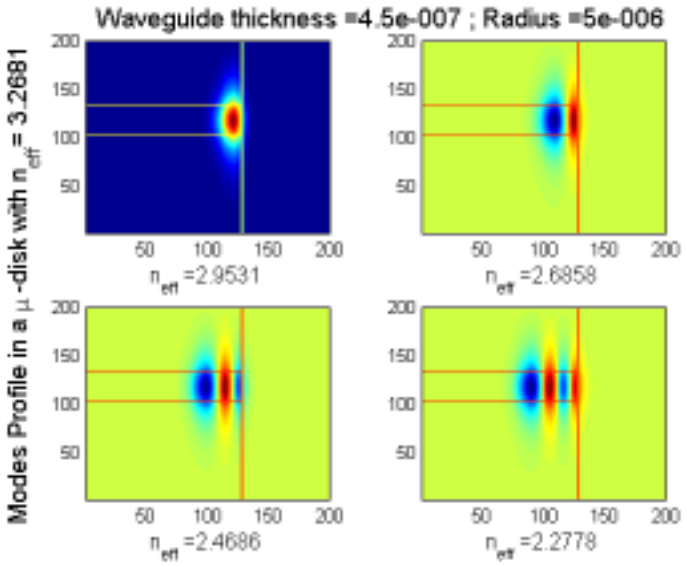
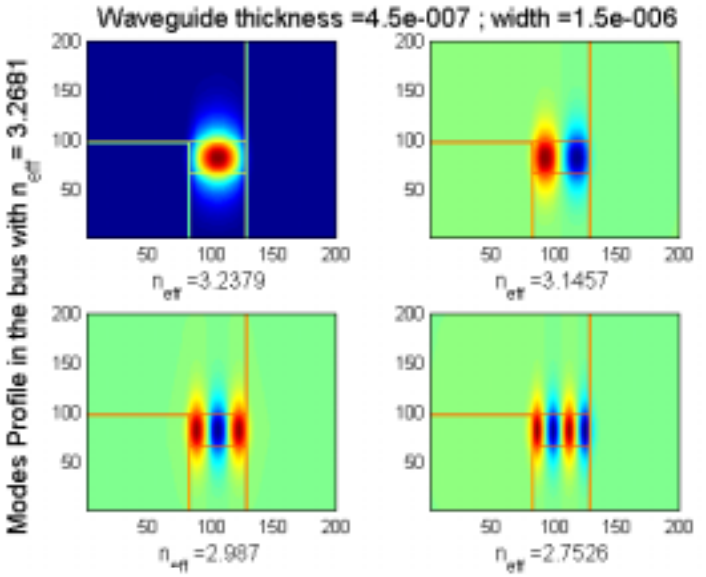
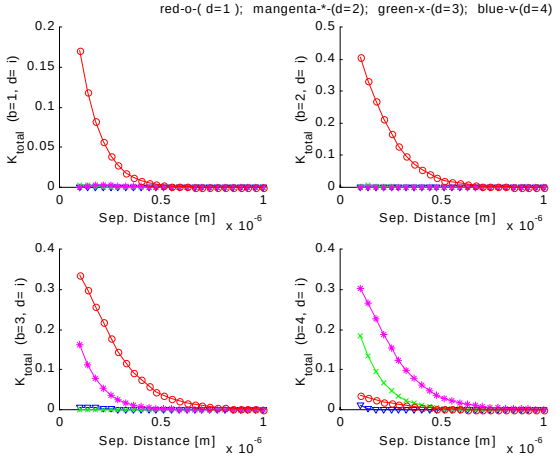
Resonator Modes



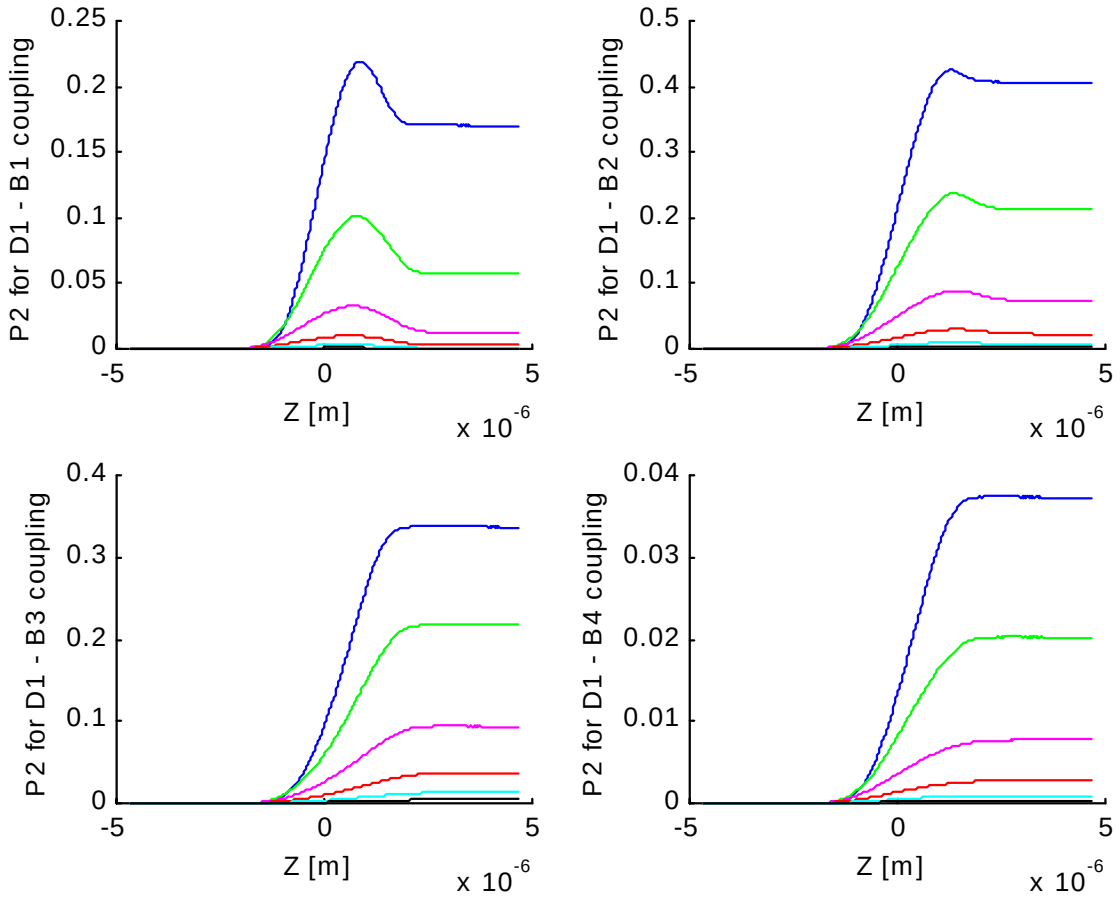
Waveguide Modes



Overlap Coefficient



Coupling Coefficeint



Technology Output

1. Low Voltage Modulators with low insertion loss
2. Vertically coupled WDM component technology.
3. Suite of sophisticated modeling tools.
4. Deliverable modulators for system trials.

Tasks and Milestones

- **Task 1 Modeling of Modulator Design and Characteristics**
  - Preliminary designs of EA and ER modulators. 3Q
  - Theoretically optimized coupling design. 8Q
- **Task 2 Modulator Fabrication Technology Advancement**
  - Resonator fabrication approach chosen. 4Q
  - Fabrication process optimized. 8Q
  - Vertical Integration approach choice. 10Q
- **Task 3 Modulator Optimization**
  - Residual loss near E_G characterized vs λ. 3Q
  - EA vs. ER choice made. 8Q
  - Ring vs Disk scattering loss measurement. 4Q
  - Measurement of Q-limited modulation limit. 10Q
  - Low resistance contact demonstrated. 4Q
  - Air bridge technology demonstration. 10Q
- **Task 4 Modulator Demonstration, Characterization and Delivery**
  - DC characterization setup complete. 4Q
  - High frequency modulation characterization setup complete. 6Q
  - Eight (8) low $V\pi$ modulators delivered in years 1-3 according to selected integrator. 12Q